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METHOD AND SYSTEM FOR DISTRIBUTING POWER TO NETWORKED DEVICES

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to networking and communications technology.

Description of the Background Art

Power over LAN™ or Power over Ethernet, is a new technology that enables DC power to be supplied to Ethernet data terminals over ordinary local area network (LAN) cabling such as Category 5 cabling. This technology enables the terminals, termed powered devices (PDs), to receive their operating power over the same Ethernet LAN connection that they use for data communication. It thus eliminates the need to connect each terminal to an AC power socket, and the need to provide each terminal with its own AC/DC power converter. The technology also enables PDs to be recognized as such by a "signature" generated by the terminal. The LAN MAN Standards Committee of the IEEE Computer Society is developing specifications for Power over LAN systems, as described in IEEE Drafts P802.3af/D3.0 or later, entitled "Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)" (IEEE Standards Department, Piscataway, N.J., 2001), which is also incorporated herein by reference. The specifications are referred to herein as standard 802.3af.

A Power over LAN system comprises an Ethernet switch and a power hub, which serves as the DC power source, along with a number of PD terminals, which communicate via the switch and draw power from the hub. The system is typically connected in a star topology, with each terminal linked by a

cable to the switch and hub. The power hub in one chassis may be integrated with the switch in a second chassis, in a console containing both chassis, in what is known as an "end-span" configuration. Alternatively, the power hub chassis may be located between the switch chassis and the terminals, in a "mid-span" configuration. DC power is carried to the loads (i.e., the terminals) over twisted pairs provided by Category 5 cabling. The end-span configuration uses twisted-data-pairs that are also used for Ethernet communication; the mid-span configuration uses spare twisted-spare-pairs that are not used for Ethernet communication.

SUMMARY

One embodiment of the invention pertains to a system for power distribution to network devices. The system includes a plurality of network switches each having an internal power supply and a plurality of ports for connecting to the network devices and an external power supply having a plurality of output ports for connecting to the network switches. The external power supply communicates power available to the network switches. Each network switch determines amounts and priority levels of power for the network devices connected thereto, sums together the amounts at each priority level, determines additional amounts and priority levels of power required beyond the internal power supply capability, and sends a power request to the external power supply. The external power supply allocates power to the network switches depending on the power requests received.

Another embodiment of the invention pertains to a method of power distribution to network devices. Amounts and priority levels of power are determined for the network devices connected to each power distributor of a plurality of power distributors. The amounts at each priority level are summed together at each power distributor, and a determination is made of additional amounts and priority levels of power required beyond an internal power supply capability of each power distributor.

In another embodiment, the method of distributing power to network devices maintaining in the switch a table of the amount and priority level

for each switch port. The table is used to allocate available power to higher priority devices when insufficient power is available to fully power all of the connected devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram depicting a conventional system for distributing power.

FIG. 2 is a block diagram depicting a system for distributing power in accordance with an embodiment of the invention.

FIG. 3 is a diagram of an intelligent power supply in accordance with an embodiment of the invention.

FIG. 4 is a diagram of an intelligent power distributor in accordance with an embodiment of the invention.

FIG. 5 is a flow chart depicting a method of power authorization by an intelligent power supply in accordance with an embodiment of the invention.

FIG. 6 is a flow chart depicting a method of generating power requests by intelligent power distributors using arbitration in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

FIG. 1 is a block diagram depicting a conventional system **100** for distributing power. The conventional system **100** includes a conventional external power supply **102**, multiple conventional power distributors **104** coupled to the power supply **102**, and multiple power user devices **106** coupled to each power distributor **102**. The external power supply **102** and the power distributors **104** are connected by way of a conventional cable assembly **108**.

The conventional power supply **102** typically distributes an equal amount of power to each power distributor **104** (load) connected thereto. This may be accomplished by either current sense and sharing, or by separate supplies within the box. The conventional cable assembly **108** typically provides power and return wires. For power-sharing purposes, a sense-signal line may

be provided. The sense signal may comprise a low-current analog signal generated using low-impedance circuitry. The sense signal is an indication of the load due to the associated power distributor **104**.

Similarly, the conventional power distributor **104** typically distributes an equal amount of power to each power user device **106** (load) connected thereto. Again, this may be accomplished by either current sense and sharing, or by separate supplies within the box. The power user devices **106** comprise loads which "demand" power from the power distributors **104** without any intelligent prioritization.

The conventional external supply **102** has a mechanism to protect itself if it is overloaded. If the load is too high, then the power supply **102** may "crowbar" to avoid damage from being overloaded. A crowbar circuit is an overvoltage protection mechanism which, when a voltage limit is exceeded, may shunt a low resistance across the power supply output terminals.

In contrast to the conventional system, an embodiment of the present invention comprises a novel power distribution system where a protocol allows the recipients of the power to indicate their requested amounts of power and priority levels thereof. The power source evaluates the power demand from the multiple recipients and balances the power demands against the available power so as to optimize the power distribution on a prioritized basis. The algorithm used by the power source is such that a device deemed "higher priority" will be given power over another device that is defined as a "lower priority." The power source replies back with an indication of allowed power usage to each recipient.

One embodiment of the invention provides a unique solution to a general problem in the "Power over Ethernet" (PoE) technology space. PoE systems are required to provide up to 15 watts per port even though many devices do not require that amount of power. For example, a 48 port switch under PoE would conventionally provide 15 watts per port so would need a 720 watt power supply. The cost of such a 720 watt supply and the packaging, air flow, and so on, to support that large of a supply is quite expensive. This problem is advantageously overcome in an intelligent way using embodiments of the present invention so as to provide power flexibly with an under-provisioned

power system (i.e. a system without full capacity to guarantee full power to all ports at all times.)

For example, one embodiment of the present invention comprises multiple intelligent PoE switches to be connected to a single intelligent external power supply (EPS), where the total power capacity of the switches and EPS is less than the theoretical maximum required (i.e. less than 15 watts times the number of ports for user devices). The system of the present invention intelligently allocates the available power capacity of the EPS to the various switches connected thereto. For instance, suppose a first switch wants 250 watts of power from the EPS and a second switch only needs 50 watts of power from the EPS. Power can be requested for each switch up to a point that would exceed the maximum total supply of the EPS, then the algorithm limits the allocated power so that the EPS capacity is not exceeded. In addition, the priority of power being distributed may be determined and utilized. For example, suppose both switches were drawing power defined as low priority. If the second switch were to suddenly need 100 watts of high priority power, the system would demand that the first switch reduce its power consumption as necessary to allow the second switch to take the needed high priority power.

FIG. 2 is a block diagram depicting a system **200** for distributing power in accordance with an embodiment of the invention. The components and interactions in this system **200** differ substantially from those in the conventional system **100** of FIG. 1. The system **200** of FIG. 2 includes an intelligent external power supply (EPS) **202**, multiple intelligent power distributors (PDs) **204** coupled to the intelligent EPS **202**, and multiple prioritized power user devices **206** coupled to each intelligent PD **202**. The intelligent EPS **202** and intelligent PDs **204** are connected by way of a cable assembly **208** having a digital communications interface. The digital communications interface may comprise, in one embodiment, a low-frequency serial interface.

One embodiment of the intelligent EPS **202** is described further below in relation to FIG. 3. In general, the intelligent EPS **202** may be configured to provide power depending on requested quantities of power, where the power requests are received from the intelligent power distributors **204** by way of the aforementioned digital communications interface. The intelligent EPS

202 may also be configured with the capability to detect whether the load from an intelligent PD **204** is exceeding an authorized amount for that distributor.

One embodiment of an intelligent PD **204** is described further below in relation to FIG. 4. In general, the intelligent PD **204** may be configured to determine amounts and prioritization of power requested by (or assigned to) the power user devices **206**.

FIG. 3 is a diagram of an intelligent power supply **202** in accordance with an embodiment of the invention. The intelligent power supply **202** comprises an external power supply to the intelligent power distributors **204**. The intelligent external power supply (EPS) **202** includes a power supply **302**, a shared power bus **304**, a EPS controller **306**, a EPS control bus **308**, EPS programmable current sense and control units **310**, and a communications channel **312**, and a cable assembly interface **314**.

The power supply **302** of the intelligent power supply **202** may be configured so as to be optimized for distribution within a low form factor and a low cost. In other words, the internal power supply **302** need not be capable of simultaneously providing full power to all user devices **206** connected via the intelligent power distributors **204** to the intelligent power supply **202**.

The shared power bus **304** couples the power supply **302** to each of the EPS programmable current sense and control units **310**. Each EPS programmable current sense and control unit **310** couples to an output port comprising a cable assembly interface **314**. Each cable assembly interface **314** connects to a corresponding cable assembly with communications interface **208**.

Each EPS programmable current sense and control unit **310** senses current to the corresponding output port and includes a switch to open or close the electrical connection from the shared power bus **304** to the corresponding output port. The current sensing may be performed by measuring a voltage across a low resistance element, and the switch may comprise, for example, a field effect transistor (FET) switch.

The EPS controller **306** is coupled via the EPS control bus **308** to each of the EPS programmable current sense and control units **310**. The EPS controller **306** comprises a processor and associated memory and is used to control the EPS programmable current sense and control units **310** and other

components (such as a fan and so on). The memory may include an external power supply table (EPS table) **316** that includes, for example, amounts and priority levels of power for each output port of the intelligent power supply **202**.

The EPS controller **306** is also coupled to each of the output ports by way of a communications channel **312**. For example, the communications channel **312** may comprise a serial communications channel or other digital communications channel. The communications channel **312** may be used, for example, to receive power requests from and power allocations to the intelligent power distributors **204**.

In accordance with an embodiment of the invention, if a power distributor **204** coupled to one of the output ports draws more current than it is allocated or authorized to draw, then the corresponding programmable current sense and control unit **310** may be utilized to switch off power to that power distributor **204**.

FIG. 4 is a diagram of an intelligent power distributor (PD) **204** in accordance with an embodiment of the invention. The intelligent PD **204** includes a cable assembly interface **402**, a power bus **403**, a power multiplexer **404**, an internal power supply **406**, PD programmable current sense and control units **408**, a PD controller **410**, a PD control bus **412**, and LAN ports **414**. In accordance with one embodiment of the invention, the power distributor **204** may comprise a network local area network (LAN) switch.

The internal power supply **406** within an intelligent power distributors **204** may be configured so as to be optimized for distribution within a low form factor and a low cost. In other words, the internal power supply **406** need not be capable of providing full power to all user devices **206** simultaneously. For example, an intelligent power distributor **202** may include, for example, 200 "Power over Ethernet" ports, each of which may provide up to 15 watts to a user device **206**. In accordance with an embodiment of the invention, the intelligent power distributor **202** may be configured with an internal power supply with a capacity that is substantially less than 200 x 15 = 3,000 watts.

The cable assembly interface **402** of the intelligent power distributor **204** couples via a cable assembly with communications interface **208**

to a corresponding cable assembly interface **314** of the intelligent power supply **202**. The power lines from the cable assembly are coupled via the power bus **403** to an input of the power multiplexer (mux) **404**. The internal power supply **406** is also coupled to an input of the power mux **404**.

The power mux **404** is controlled by the PD controller **410** via the PD control bus **412**. In accordance with one embodiment of the invention, the PD mux **404** is controllable so as to switch available power (from the power bus **403** and/or the internal power supply **406**) to the ports **414** of the intelligent PD **204**. For example, the intelligent PD **204** may comprise a network switch with two banks (left bank and right bank) of twelve LAN ports **414** each. In one specific implementation, the power mux **404** may be controllable so as to switch power from the internal power supply **406** to the left bank, to the right bank, or to both banks of ports. Similarly, the power mux **404** may be controllable so as to switch power from the external power supply **202** (via the power bus **403**) to the left bank, to the right bank, or to both banks of ports. Of course, in other implementations, more than two banks may be used, and the banks may have other numbers of ports.

Each PD programmable current sense and control unit **408** senses current to the corresponding port **414** and includes a switch to open or close the electrical connection from the power mux **404** to the corresponding port **414**. The current sensing may be performed by measuring a voltage across a low resistance element, and the switch may comprise, for example, a field effect transistor (FET) switch.

The PD controller **410** is coupled via the PD control bus **412** to each of the PD programmable current sense and control units **408**. The PD controller **410** comprises a processor and associated memory and is used to control the PD programmable current sense and control units **408**, the power mux **404**, and other components (such as a fan and so on). The memory may include a power distributor table (PD table) **420** that includes, for example, amounts and priority levels of power for each port **414** of the intelligent PD **204**.

In accordance with an embodiment of the invention, the priority level of power for each port **414** is dependent on the identity or type of network device **206** connected to the port **414**. For example, higher priority devices may

include IP-enabled telephone devices. As another example, higher priority devices may include wireless access ports. In accordance with another embodiment, the priority levels of power for the ports **414** may be configurable into the PD table by a network administrator.

The PD controller **410** is also coupled to each of the cable assembly interface by way of a communications bus **416**. For example, these communications may comprise serial communications or other digital communications. The communications bus **416** may be used, for example, to send power requests to and power allocations from the intelligent power supply **202**.

In accordance with an embodiment of the invention, if a user device **206** coupled to one of the ports **414** draws more current than it is allocated or authorized to draw, then the corresponding PD programmable current sense and control unit **408** may be utilized to switch off power to that user device **206**. In one implementation, capacitors **418** are advantageously coupled to the power lines going to each port **414**. These capacitors **418** may be used to prevent a temporary surge of power drawn from one port **414** from adversely affecting the user devices **206** coupled to the other ports **414**.

FIG. 5 is a flow chart depicting a method **500** of power authorization by an intelligent EPS **202** in accordance with an embodiment of the invention. In a preliminary step, registers within the intelligent EPS **202** may be initialized **502** to set the registers to their default values.

Serial (or other digital) communication between the intelligent EPS **202** and the intelligent PDs **204** is then initiated **504**. For example, the initiation **504** of communication may be implemented by the intelligent PD **204** pulsing an interrupt signal to indicate that it is ready to communicate, or by a handshake between each intelligent PD **204** and the intelligent EPS **202**.

The intelligent EPS **202** calculates and communicates **506** the power available per port to the intelligent PDs **204**. The communication is performed by way of the digital communication channel therebetween. In one implementation, the calculation may comprise simply dividing a total power capacity of the EPS **202** by the number of output ports with intelligent PDs **204** connected thereto. For example, if the power capacity of the EPS **202** is 600

watts, and four output ports have power distributors **204** connected thereto, then the power available per port is calculated to be 600 watts/ 4 PDs = 150 watts per PD. In an alternate embodiment, the total power available may be communicated instead of the power available per port.

The intelligent EPS **202** then receives **508** power requests from the intelligent PDs **204**. These power requests may include an amount of power requested at each priority level from each intelligent PD **204**. For example, each intelligent PD **204** may determine amounts and priority levels of power for the network devices **206** connected thereto, sum together the amounts at each priority level, determine additional amounts and priority levels of power required beyond the internal power supply **406** capability, and send a power request with these additional amounts and priority levels of power to the intelligent EPS **202**.

In one embodiment, the intelligent PDs **204** may advantageously arbitrate amongst themselves in the process of generating the power requests. A high-level process for such arbitration is described below in relation to FIG. 6. In an alternate embodiment of the invention, the power requests may be generated individually by the intelligent PDs **204** (without mutual interactive arbitration therebetween). In such an embodiment, the intelligent EPS **202** may be configured to apply an algorithm that allocates the available power to the higher priority requests without exceeding the total capacity of the EPS **202**.

After receiving the power requests from all the intelligent PDs 204, the intelligent EPS **202** totals the requested amounts to check as to whether the total requested amount is within the total capacity of the EPS **202**. If so, then the power requests are acknowledged **510** by the EPS **202** sending acknowledgement messages to the PDs **204**. The acknowledgement message indicates the power being authorized and allocated to each PD **204**. If the total capacity is exceeded by the total requested amount, then, in one embodiment, the intelligent EPS **202** applies an algorithm that allocates the available power to the higher priority requests without exceeding the total capacity of the EPS **202**.

The system **200** thus allocates power from the intelligent EPS **202** to the intelligent PDs **204**. Subsequently, the system is configured to detect an imbalance or port change. For example, an imbalance may occur if one PD **204** begins to draw power beyond its authorized and allocated amount. A port

change refers to the addition or removal of a PD **204** from the ports of the EPS **202**. If an imbalance or port change is detected, then the method **500** loops back to the step where communication between the EPS **202** and PDs **204** is initiated **504**, and the method **500** continues on from there to re-allocate the available power.

FIG. 6 is a flow chart depicting a method **600** of generating power requests by intelligent power distributors **204** using arbitration in accordance with an embodiment of the invention. In a preliminary step, registers within each intelligent PD **204** may be initialized **502** to set the registers to their default values.

The intelligent PDs **204** await and look for a signal to arbitrate power requests. When such an arbitration signal is received **604**, then the intelligent PDs **204** arbitrate power requests amongst themselves. The arbitration messages may be communicated by way of the digital communications channels linking the PDs **204** to the EPS **202**, or they may be communicated by way of separate communication channels (not illustrated) between the PDs **204**.

In one embodiment, the arbitration **606** may be implemented using a master-slave arbitration algorithm. In such an embodiment, one PD **204** is designated as the master, and the other PDs **204** are designated as slaves. Various master-slave arbitration algorithms are known to those of skill in the pertinent art, and it is contemplated that the scope of the invention should encompass various master-slave arbitration algorithms. In an alternate embodiment, the arbitration **606** may be implemented using a peer-to-peer arbitration algorithm. In such an embodiment, none of the PDs **204** is designated as the master. Various peer-to-peer arbitration algorithms are known to those of skill in the pertinent art, and it is contemplated that the scope of the invention should encompass various peer-to-peer arbitration algorithms.

Once the arbitration **606** is complete, then the arbitrated power requests are provided **608** from the intelligent PDs **204** to the intelligent EPS **202**. Specific registers may be used to provide the power requests. Thereafter, the process **600** may loop back to initialize **602** the registers and await **604** another arbitration signal.

In one alternate embodiment of the invention, the intelligent EPS **202** and the multiple intelligent PDs **204** may be integrated together in a single power distribution unit or chassis. In this embodiment, the EPS **202** would no longer be "external", rather it would be internal to the unit. The multiple PDs **204** would then comprise subunits of the integrated power distribution unit. Such an integrated power distribution unit would be advantageously intelligent and flexible in distributing its available power on a prioritized basis.

In the above description, numerous specific details are given to provide a thorough understanding of embodiments of the invention. However, the above description of illustrated embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise forms disclosed. One skilled in the relevant art will recognize that the invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures or operations are not shown or described in detail to avoid obscuring aspects of the invention. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

These modifications can be made to the invention in light of the above detailed description. The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of the invention is to be determined by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.